SOLAR ENERGY

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PRICES SUBJECT TO CHANGE

16. Abstract

Water pumps, solar power stations, air conditioners, fresh-water stills, "solar homes," solar cookers, fruit driers, devices for [low temperature] steaming of reinforced concrete members, "solar refrigerators," solar hothouses, welding and melting of metals presents a far from complete list of the devices and areas of the possible broad use of solar energy. In the Ninth Five-Year Plan, the country's first plant of solar equipment is to be built in the Uzbek city of Bukhara for the series production of several of these products designed by Soviet scientists. The authors of the booklet also tell about longer-range prospects for mastering solar energy -- one of the most important sources of renewable kinds of energy.

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AUTHORS' ABSTRACT

Solnechnaya Energetika [Solar Energy], Umarov, Giyas Yakubovich, corresponding member, Uzbek SSR Academy of Sciences, and Yershov, Anatoliy Andreyevich, engineer, Moscow, "Znaniye" Press, 1974 (Novoye v zhizne, nauke i tekhnike. Seriya "Nauka o Zemle" [Advances in Life, Science and Technology. "Science of Earth" Series], 1. The series has been published monthly since 1966). 64 pp.

People have tried to use the Sun's energy even in remote antiquity. This booklet tells how the problem is being solved in our time.

Water pumps, solar power stations, air conditioners, fresh-water stills, "solar homes," solar cookers, fruit driers, devices for [low temperature] steaming of reinforced concrete members, "solar refrigerators," solar hothouses, welding and melting of metals presents a far-from-complete list of the devices and areas of the possible broad use of solar energy. In the Ninth Five-Year Plan, the country's first plant of solar equipment is to be built in the Uzbek city of Bukhara for the series production of several of these products designed by Soviet scientists. The authors of the booklet also tell about longer-range prospects for mastering solar energy -- one of the most important sources of renewable kinds of energy.

SOLAR ENERGY

G.Ya. Umarov and A.A. Yershov,
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Fuel ... from the Heavens /3*

A layer of unique coal half a meter thick is formed every year over all of Central Asia. The amazing layer covers fields and mountains, streets and squares of cities, roofs of homes, and gardens. It does not have to be brought in from anywhere -- you just take this coal and use it! A year goes by and the layer is again renewed. It is simply inexhaustible. But even though we all move about by means of this strange fuel, nearly no one pays it attention. Of course, the energy of this amazing coal disappears not at all -- it is simply dissipated into the atmosphere.

What then is behind this invisible coal? Scientists named it "yellow coal" -- solar energy! Calculations show that in Uzbekistan over each square meter enough of it falls so that in terms of calories it is equivalent to a layer of Angren lignite nearly half a meter thick. The Transcaucasus, Crimean and other southern parts of the country and many states of Asia, Africa, and America are rich in "yellow coal."

However, this enormous treasure thus far has remained nearly unused. Still, there is not enough fuel available. In some places this is felt thus far not as appreciably, while in others the fuel shortage has become an acute problem. But this is true overall for our entire planet. Some economists claim that the last ton of petroleum will be extracted from the Earth already at the dawn of the coming 21st century. As for regular coal and natural gas, their reserves will also not last for very long.

But the needs of the global population for energy will rise /4
very rapidly. In fact, without energy technical progress is inconceivable. Scientists have calculated: from the beginning of its existence mankind has used up 850,000 billion kWh of primary energy, that is, energy formed through the combustion of different kinds of fuel. It has been used up very rapidly in the last hundred years.

But in fact the growth of the power resources of our planet will not halt either in the future. It cannot be met sufficiently long either by the reserves of radioactive elements in the Earth's

* Numbers in the margin indicate pagination in the foreign text.

crust -- the fuel of the vigorously growing field of atomic power engineering. Uranium and thorium resources are also not infinite, just like all ordinary kinds of fuel.

Mastery of the thermonuclear reaction would long supply mankind with energy, but enormous difficulties lie yet on this path.

Thus, the Earth's population is growing, its energy needs will climb. But where can energy be extracted from? Perhaps, actually mankind is threatened with a "energy famine?"

No, everything is not so hopeless. On Earth mankind has not yet been able to harness the reaction of thermonuclear synthesis and to make it controlled. And it is precisely in this area that scientists are pinning their hopes in calculating to meet the energy needs of mankind. But in fact this kind of reaction occurs in stars, including also on the one closest to us -- the Sun. Essentially, our daytime star is a gigantic thermonuclear reactor which requires each second approximately 4 million tons of hydrogen, converting it into helium. As a result enormous amounts of energy are given off, emitted in the form of light and various particles.

Only a small fraction of the collosal energy -- roughly one-two billionth -- reaches our planet. Is this much? It is quite sufficient to evaporate the Sea of Azov in a few minutes. In a year in fact, the Earth receives from the Sun more energy than it contains in all known world fuel deposits. And it is precisely the Sun that is the primary source of all forms of energy that have found wide use in the economy of the planet. Fossil fuel essentially is stored solar energy preserved in remains /5
of the plant kingdom of past epochs. Rivers also owe their energy to the Sun, being replenished with water evaporated by the daytime star from the surfaces of oceans and seas.

The storehouse of "solar fuel" is inexhaustible for mankind. Therefore it is not coincidental that scientists are directing their thoughts with growing expectations toward this practically eternal source of light and heat. It sends to Earth amounts of energy that many times exceed man's need for energy.

Thus perforce the question arises: why then has not solar energy thus far found wide use in industry? The point is that it is very dispersed. This means that one must find and develop methods of concentrating and accumulating solar energy. How scientists are solving these problems vital to our planet's future and unlocking the keys to the Sun, we will attempt to describe in this booklet.

In our country a new important stage in expanding research in mastering solar energy is linked to the Ninth Five-Year Plan. "The primary goal of the Five-Year Plan is to ensure a large rise in the material and cultural standard of living of our people through high rates of expandsion socialist production, its greater efficiency, scientific-technical progress and faster increases in labor productivity" states the Directives of the XXIV Congress of the CPSU on the Five-Year Plan for the growth of the national economy of the USSR in 1971-1975.

In the directives, scientists are given the goals of "improving methods of transforming energy," "developing ... economical methods of obtaining ultrapure materials," developing "methods of selection for growing high-yield plant varieties," "the scientific fundamentals of the conservation and transmission of energy to improve the environment of man and for the best use of natural resources." Scientists engaged in research in different directions related to using solar energy in the national economy will also make their contribution to solving the problems posed /6 for Soviet science by the XXIV Congress of the CPSU. Studies in this direction are being carried out under the coordinating plan of the State Committee of the USSR Council of Ministers for Science and Technology for 1971-1975.

Leading institutes have been assigned for working with specific problems. The All-Union Institute of Current Sources is responsible for developing different kinds of solar energy converters, in particular, photoelectric converters and also for high-temperature studies. The Power Institute imeni G.M. Krzhizhanovskiy is the ranking scientific establishment in solar thermal installations and several solar energy converters (thermoelectric). The Physico-Technical Institute of the Academy of Sciences of Turkmenia became the ranking research center in developing solar air conditioners and fresh-water stills. The Physico-Technical Institute of the Academy of Sciences of Uzbekistan is responsible for developing solar energy concentrators, solar thermal devices, and solar power plants based on the Stirling engine.

Investigations in a new area -- photoenergetics of plants -- have gained broad scope in recent years in the scientific centers of the Russian federation, the Ukraine, Kazakhstan, Uzbekistan, and Moldavia.

Great attention to mastering solar energy is also being shown abroad. Important results in this area have been gained by scientists in France, the United States and Japan. Interest in this problem is shown by the young states of Asia and Africa. Several of these countries lack sufficient fuel reserves, therefore the broad introduction into their economies of the achievements of solar power engineering would play an extremely vital role for them. So scientists of many developing countries have expressed a desire to cooperate with Soviet scientists in research in solar power engineering. Joint efforts in mastering solar energy have been begun by scientists of the USSR and the United States.

Since time immemorial people have tried to learn how to use solar energy. This is borne out by chronicles and ancient books of the Egyptians, Greeks, and Romans. Many ancient peoples worshipped the Sun and believed it to be a deity. They intuitively sought in it the source of life, the primary basis of all motion on our planet. The cult of the heavenly light by day existing in Central Asia persisted for us in the images of the Sun god in the coin of the mighty Kushanskiy rulers.

Even in antiquity people pondered how to trap the Sun's rays. Even then the properties of lenses and curved mirrors to collect the rays at a focus was known. Using burning glasses, the vestal virgins in ancient Rome were able to bring sacred fire to sacrifices at the temple of the goddess Vesta.

The great Archimedes reported the possibilities of concentrating solar rays in his book, On Burning Glasses. Linked with his name is the legend of setting afire with mirrors a Roman fleet besieging Syracuse.

During the early Middle Ages scientists of Central Asia also knew of the ability of lenses to collect solar rays at one point. Berouni and his no less famous contemporary Avicenna were acquainted with the focusing property of lenses and mirrors. Thus, Avicenna in Danish-Name [Book of Knowledge] explained the thermal action of solar rays and the optical properties of a lens this way: "Ignition through a magnifying glass takes place because in it there is a point receiving the rays from all sides. This point is strongly illuminated and therefore strongly heated." Burning mirrors, asserted the scientist, have the same properties as magnifying glasses. In those remote times a mirror was a polished metal surface on which mercury was periodically deposited.

In 1741, the genius and Russian scientist M.B. Lomonosov presented to the Petersburg Academy of Sciences a paper on the possibility of making a "burning instrument" by concentrating /8
solar rays with lenses and mirrors.

Many scientists and engineers today, in our time, are working on the idea of trapping sunlight and forcing it to work for us. But realizing these ideas involves great outlays. Therefore even today the problem of building inexpensive, simple, and efficient solar power devices remains one of the most important in this field of science. Soviet solar power engineers are contributing to its solution. Old-timers living in Tashkent probably still well recall the gigantic reinforced concrete sunflower turning toward the Sun over the buildings of a local canning plant. The bowl of a ten-meter paraboloid covered with squares of mirrors stood here for many years. The strange structure captured the attention of everyone driving along one of the busiest arterials of the capital of Uzbekistan. This solar ray collector during the first postwar years was built by F.F. Molero, working at the solar grounds of the Moscow Power Institute imeni G.M. Krzhizhanovskiy then existing in Tashkent. The collector was designed to supply thermal energy to the canning plant. This was a unique installation. At the hottest point where the solar rays intersected the temperature exceeded 1000°.

However, as it was later found, in building this engineering structure the minor deviation of the coefficients of linear expansion of glass and cement securing the glass to the reinforced concrete proved to be neglected. This then ruined an excellent structure: the glass of the mirror-collector cracked owing to the enormous internal stresses induced therein.

Tashkent solar power engineers studied this problem closely and decided to do entirely without cement in a collector of their design. But how will the mirrors be held? In free mounting! The idea was simplicity itself. The researchers took plates of ordinary window glass coated on one side with an amalgam. Mounting these plates on five supports to the framework of the collector and obtaining a concave surface thereby proved not difficult. And, particularly important, the glasses in free mounting now no longer cracked from thermal expansion. Some of these devices /9 situated in the proving grounds of the Physico-Technical Institute in Tashkent have a reflecting surface area 5 m in diameter.

Mirrors of polished glass are excellent solar ray collectors. But making a mirror of this kind of a large size is very expensive. And the greater its diameter, the bigger are the costs in making it. Perhaps, one large mirror could be replaced with dozens of smaller ones? Calculations and tests in the Physico-Technical Institute of the Uzbek SSR Academy of Sciences confirmed the soundness of the approach taken. Small mirrors are /10 much simpler to make and so much cheaper.

Both large and small solar ray collectors have been constructed of mirror-facets at this institute. The diameter of one solar ray collector is 5 m. Its construction involved 60 facets -- round mirrors 60 cm in diameter. They were all mounted on a metal framework so that sunlight could be concentrated with high accuracy. At the focus the temperature goes up to nearly 2000°. In fact around this focus -- at the focal spot -- the mean temperature proved to be 1000-2100°. These devices are most promising in solving many practical problems.

But still the disadvantages of glass could not be overcome. /11 In fact this was too heavy a material and so in building large collectors of glass one had to assemble quite solid metal structures for the supports. This means that even when a definite size is achieved it will be disadvantageous to use these

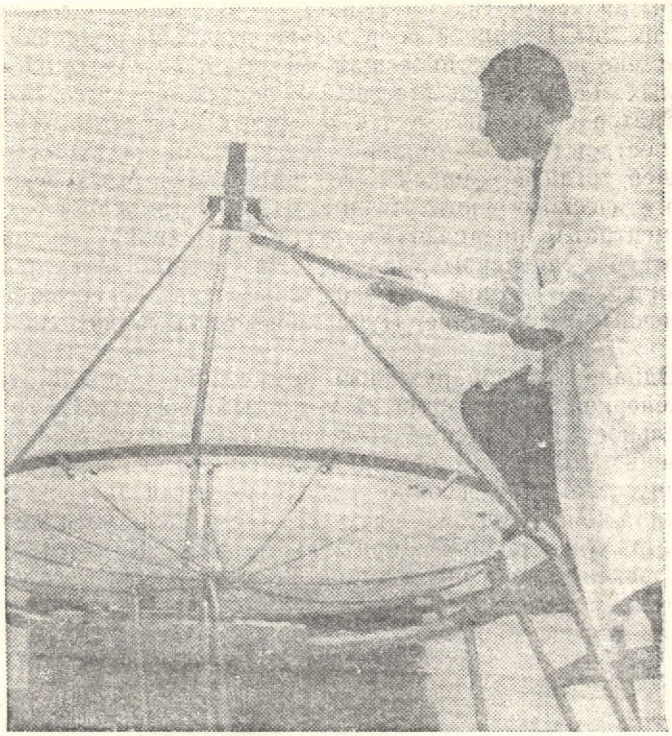

Fig. 1. Metal will melt in the focus of this simple and cheap collector, though its reflector is made of sectors of ordinary window glass which are given a certain surface curvature.

collectors. But researchers are still looking. And if they use polymeric films? They tried lavsan. A metallized film of this material proves to be light and only slightly inferior to glass in optical properties. Tests of this film were made at the solar proving grounds of the Physico-Technical Institute of the Uzbek SSR Academy of Sciences. It turned out that the film retains its initial qualities for only several months. How can its service life be extended, bearing in mind that above all it must not lose its high reflectivity? A graduate student at the institute suggested coating the film with varnish containing special additives. Even the first tests showed that in this form film can serve for much more than a year.

Scientists are also following the approach of lowering the weight of the structures on which the reflecting surfaces rest. Taskent solar power engineers have tried replacing metal with asbestos-cement. It turned out to be lighter, but not as light as scientists wished. Next the skeleton of the concentrator was made of foam-polystyrene, after which foam-plastics were also tried. But foam-polyurethane proved best.

Rays are collected at the focus. And how can the concentrated energy be used best? Here studies are proceeding in several directions. Staff members at the Physico-Technical Institute of the Uzbek SSR Academy of Sciences are working to improve the method of transforming solar energy into electrical using a Stirling engine.

Amazingly, the patent for this thermal machine which modern technology adopted into its arsenal only quite recently was issued more than 150 years ago. The inventor was a Scottish monk

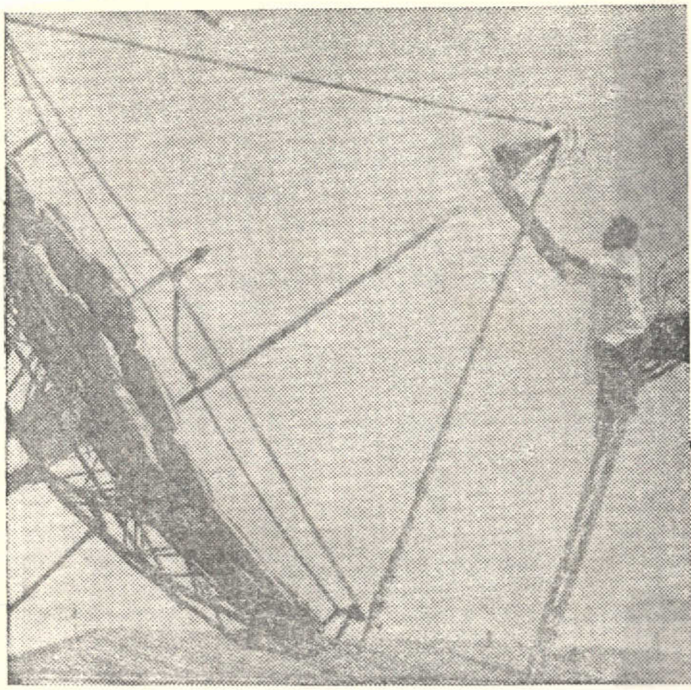

Fig. 2. The temperature goes up to 2000° at the focus of this collector (5 m in diameter) constructed of small mirror-facets of unpolished glass. A board inserted in this solar light spot dries up in a flash.

Robert Stirling, whose name now has been given to this type of engine. In it, as in a steam engine, thermal energy is obtained through external combustion (in contrast to the internal combustion engine in which fuel gives up its energy directly to the engine cylinders). How- /12
ever, the working body of the Stirling engine is not steam, but gas circulating in a hermetically sealed circuit. Theoretically, the efficiency of this machine can be very high -- close to the efficiency of the ideal Carnot cycle. The advantages of the Stirling engine are absence of operating noise, balanced performance of drive, and the ability to function in a vacuum, underwater and in other unusual conditions.

Any source of fuel -- liquid or solid fuel, atomic energy, thermal collectors ... can serve to power this engine. But likely one of the most promising sources of energy for the Stirling engine is sunlight. Entering the "hot" chamber of the engine, they compel hydrogen, helium, or another suitable gas to circulate through the closed loop; this gas then drives the engine pistons. By converting the chemical energy to electrical takes place in the usual manner.

The efficiency of the engine depends on the difference between the temperatures of the "hot" and "cold" engine chambers. The higher this difference, the higher the engine efficiency. In other foreign prototypes of this engine gas is heated to 750° and cooled down to 20° Celsius (water is usually used in cooling the gas). This large temperature drop is easily achieved using solar ray collectors. We already noted that Uzbek solar power engineers were able in their device to achieve an even greater drop, in fact at its focal spot where the "hot" chamber of a Stirling engine is positioned the temperature is 1000-1200°. This permitted raising the efficiency of the engine already to 30%. In addition, workers at the Physico-Technical

Institute made several improvements in the design of the Stirling engine. Their priority in this effort was confirmed by authors' certificates for the inventions.

Energy from the solar "light spot" can be tapped also be means of the so-called thermoelectric converters; their operating principle was also discovered in the nineteenth century. It is based on the fact that when a junction of two wires made of dissimilar metals are heated, current appears. It turned out that /13 if instead of metals one selects two different semiconductors, the coefficient of this thermoelectric generator will be raised considerably. It is precisely this idea that was suggested 40 years ago by Academician A.F. Ioffe who predicted the great future of thermoelectricity. Thus far the efficiency of thermoelectric generators is only 5%. However, in thennear future scientists hope to bring this figure to 10%.

The operation also of the thermal emission electric generator is also based on the principle of converting energy through heat into electricity. In its layout, the thermal emission electric generator resembles an ordinary radio tube in which emission occurs when the cathode (negative electrode) is heated -- the emission of electrons falling on the anode (positive electrode) and there producing current in a closed circuit. In order to achieve in this case a relatively high efficiency, one must heat the cathode roughly to 2000°. Solar rays collected by mirror-concentrators achieve this temperature. A key advantage of thermal emission converters is the possibility of obtaining current at very high densities -- dozens and even hundreds of amperes per square centimeter of irradiated surface. Specialists calculate that by this principle converters with efficiency of 20-25% can be built, but investigators still expect many technical difficulties.

Using solar ray collectors gases and vapors of alkaline metals can be heated to high temperatures in order to produce an electrically conducting plasma. If the plasma is passed through a magnetic field, then by the laws of electrodynamics electric current is generated. In contrast to an ordinary electric generator, here the current will pass not through a copper coil, but through the plasma itself. This current can bettapped with electrodes. The operation of magnetohydrodynamic (MHD) generators is based on this principle; scientists of many countries are working on building these generators. They are drawn by the high efficiency of these devices, promising to sharply surpass the corresponding indicator for thermal electric power stations. However, there are also several difficulties along the path of /14 thisttempting technical idea, in particular, the production of plasma remains a complicated problem. Perhaps it can be solved with concentrated solar rays? The future will tell.

It would be ideal to directly transform solar energy into electrical. When light falls on some metals, electrons are ejected from them. This phenomenon came to be called the photoelectric effect. The famed Russian scientist A.G. Stoletov (1839-1896) was a pioneer in research in this area. The operating principle of exposure meters used by photographers and film makers is based on this effect. But this device gives extremely little energy -- only one-thousandth of the radiant energy of the Sun it uses. However, with the appearance of semiconductors it was possible to achieve important practical results in the direct transformation of light energy into electrical.

Photoelectric converters or solar batteries are fabricated from sheets of silicon or other semiconductor material similar to it in properties. When solar rays strike a semiconductor, electrons are ejected from the atoms of the material, leaving behind positive charges. The electrons ejected by the radiant flux travel from one silicon layer to another. This movement of charges then causes electric current. From a set of identical elements, semiconductor plates, entire panels are assembled. They in fact are veritable small power stations without steam boilers and dynamos.

The efficiency of a solar battery today has reached roughly 10%. The maximum efficiency theoretically possible for silicon is 22%. And scientists working on improving solar batteries are pushing toward this figure. But besides silicon, no small number of other semiconductors have been discovered and are in use, where the theoretical efficiency for these can even be much higher.

And if a concentrated beam of solar rays is directed at a
semiconductor battery? Then, as it turned out, the photoelectric /15
generator can be made to operate much more efficiently (in fact, the generation of current depends on the degree of illumination). True, silicon batteries cannot withstand a large temperature rise, but semiconductors that do not fear "blinding" by sunlight have been found.

"Hot Box"

However, our account of "traps" of solar rays proved to be thus far incomplete. We have said nothing about the most widespread trap -- the "hot box." An example of it is an ordinary hothouse. Easily penetrating through the transparent glass, sunlight heats the soil of the hothouse. As a result it also emits energy. But not in the form of invisible, infrared rays. Glass is not transparent for these rays, and so it does not let them pass to the outside. Thus solar energy falls into a "trap."

If one places several series of glass panes, one can raise the air temperature in the "hot box" up to as high as 250°. This result was achieved even before the war in experiments by Tashkent solar power engineer Konstantin Grigor'yevich Trofimov, who used eight series of glass sheets. In fact the design of the simplest water heaters is based on the "hot box" effect. Of course here one must recall that part of the radiant energy is absorbed by the glass panes, therefore in practice the most optimal variant is used -- one or two series of glass panes, enough to produce hot water.

Hothouses, greenhouses, conservatories. Very common structures. Therefore improving these simplest devices utilizing radiant energy promises great economic benefits. But what then are the possibilities?

Let us start with glass. Thus far it remains one of the basic materials in building greenhouses above all because it has the necessary optical properties -- sunlight is admitted with least losses and then partially retained. But in fact glass is brittle, easily breakable. Rain, snow, strong winds, not to speak of /16
hail ... Thousands and thousands of square meters of greenhouse glass are destroyed.

In our windows, in the showcases of stores, everywhere where glass does not lie but stands, it can support its own weight, which often is quite high. All one needs to do is lay out glass horizontally and it loses its ability, it becomes weak. This is one more drawback of glass. Millions of square meters of glass surface have to be reinforced in hothouses on a palisade of supports. But this adds to the costs of building hothouses and complicates interior layout, therefore also hothouse maintenance.

If one makes ordinary glass corrugated like corrugated iron, it becomes an order of magnitude, as engineers put it, that is 10 times stronger. It now is nearly impervious to bad weather. The dimensions of the glass sheets as such can be much increased. This means that fewer props are needed and hothouse construction turns out to be much cheaper. Now these glass sheets are being proposed for use in erecting hothouses by co-workers at the Physico-Technical Institute of the Uzbek SSR Academy of Sciences.

Scientists are also improving the optical properties of glass. Glass still allows heat rays to pass from hothouses. Therefore, the idea of researchers is to develop glasses that would be entirely opaque to infrared radiation and reliably trap heat in the hothouse. A group of scientific co-workers at the Power Institute imeni G.M. Krzhizhanovskiy suggested coating the glass with a film of tin dioxide. The technology of this process is relatively simple and has already been mastered industrially. Glass treated in this way is called selective by the scientists since it has the selective property of regulating the one-way transmission of radiant energy.

Two years of tests of hothouses and greenhouses covered with selective glass established that the temperature in these structures is 9-10° higher than in ordinary structures. In hothouses plants die without heating during night frosts of minus 5° or lower. But in hothouses equipped with selected glass plants do not fear ambient air temperature drops to minus 12°.

But if films are used in place of glass? Scientists and engineers have also thought about this. Today polyethylene film is finding the broadest applications. It can serve for short periods as a covering for hothouses. During the three summer months it breaks down under solar exposure and not only loses strength, but also other mechanical properties. Also, polyethylene is inferior in optical properties to window glass, and so the hothouse effect of the synthetic coating is much weaker. /17

It would be a good idea to make polyethylene film so that it could take exposure to the Sun for several years. The advantage of this would be tremendous! For example, two harvests of cotton could be reaped beneath film, for its growing period in hothouse conditions would be shortened owing to the high concentration of carbon dioxide gas. And it would only take 9 months for seeding and harvesting to be carried out twice. However, a polyethylene capable for all this time of withstanding the rays of the scorching sun of Uzbekistan would be needed.

And polyethylene film has one more flaw -- it is difficult to wash free of dust. Particles of dust literally eat into it and it is impossible to get rid of them. This is a serious problem that has to be solved, although even now an approach has been found, which when pursued can mean better wettability of polyethylene film. Here we refer to a gas-charging chamber where ion bombardment of film can improve film wettability.

There is no shortage of problems of concern to solar power engineers. But even what scientists have been able to do in this area can markedly alter our daily life and introduce considerable innovations and improvements into vital industrial processes.

City of the Sun

In this amazing city many of the most vital operations are done by the Sun -- it heats homes in winter and cools them in summer, it heats water for showers and boils water for meals, it dries fruits and synthesizes chemical products at plants ...

Let us go into one of the little homes in this unsual solar city. It is hot on the streets -- more than 40°, while inside the cottage it is amazingly cool for summer. This cool condition is due to the Sun. We open the faucet in the bath and from the shower gushes forth a caressing warm "rain," in the kitchen we have hot water for washing dishes. This is also the Sun's doing. The master of the house is having someone to dinner. As if it was entirely commonplace, but in fact the dinner was prepared with the help of the sun. And here the helio tea for some reason appears to be more aromatic and flavorful than ordinary tea.

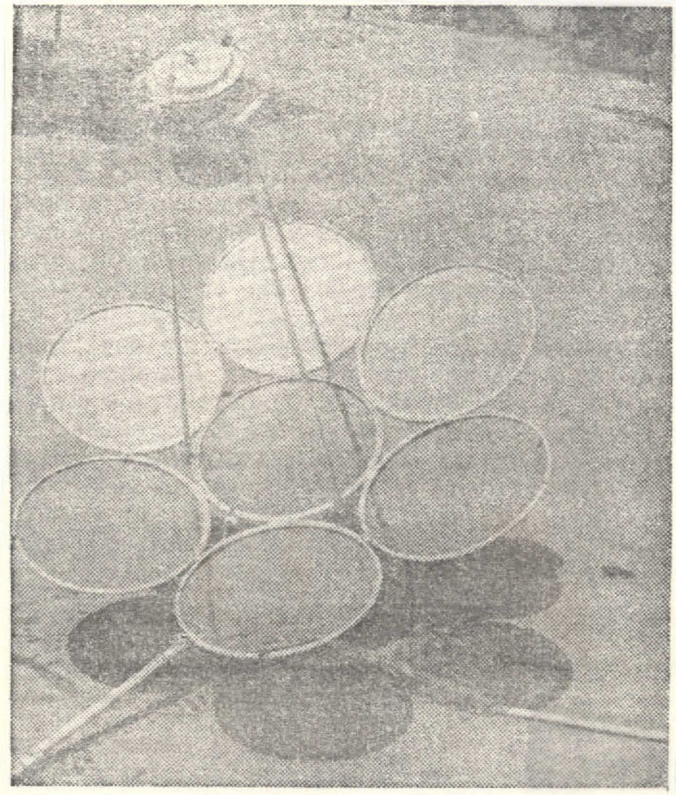

Fig. 3. Solar cooker designed at Physico-Technical Institute of Uzbek SSR Academy of Sciences

"In winter," the cottage master shares with us, "we have no need to think about fuel. Our precious Sun will /19 be concerned about all of this. It will warm our house, light our rooms, without even mentioning the many household services that we will enjoy with its help -- it will bring us water from the well and in general do a great deal of other useful work..."

Let us continue our journey through this amazing city. Not far from our little house is a large food industry enterprise. Here the Sun has been ordered to dry fruits and vegetables, prepare fruit concentrates, pastes, and juices ... Alongside is a wing of a chemical plant where solar rays are used in conducting photochemical reactions for manufacturing valuable compounds.

Let us go on further -- in front of us are the grounds of a scientific research institute of construction materials. Here materials are tested for aging with concentrated solar rays. Because of this amazing machine, the time required to age materials has been cut 5-10 times compared to natural conditions. These tests make it possible to develop very long-lasting materials.

You say that all of this is a dream, fantasy! There is no city like this on Earth. Well, a whole city as we have been imaging does not yet exist. But solar homes do actually exist.

One can also become familiar with solar refrigerators and solar cookers, solar driers, and many other units to which the label "solar" has been fixed. This can be done in Ashkhabad, Tashkent, Bukhara, Karshi,...

How then is the Sun able to "do" the most widely varied household and production assignments of man? First let us learn something about the layout of a solar cottage. It is quite ordinary, and you can even build it from standard plans. Only its roof is unusual; it is a "hot box" we have come to know about, installed on the southerly side of the home at an angle of 50° to the horizon. This boiler-roof can convert solar energy into heat.

Flat water heaters whose designs were developed in the Physico-Technical Institute of the Uzbek Academy of Sciences, like tile, cover this unusual roof. These water heaters are built /20
of standard factory-made parts -- corrugated rolled metal. By the way, the sides of the well known trailers for baleless transportation of cotton are made of the same rolled stock. For better absorption of sunlight, the metal is blackened. The sheets of rolled stock are coated from above with glass, and now we have a "hot box." Within it water circulates. Simple, cheap and efficient. Experiments by Tashkent solar power engineers showed these water heaters to have efficiencies a full one-third above the efficiencies of earlier-used devices with tubular structure.

The roof-boiler supplies water at 60-70° Celsius. If hotter water is needed, one can use a two-layer glassing for this boiler. Sun-heated water is used for warming rooms by means of ordinary radiators. Some of the hot water goes to the kitchen, to the bath, and so on. When there is no need to heat the rooms, the hot water is sent to heat-insulated tanks -- storage vessels. The heat stored in them can be used during cloudy weather and at night. In the event of prolonged bad weather of course a standby heating system has to be resorted to.

The same solar installation on the roof and the system of radiators in the rooms in summer can serve also to cool the rooms. Whereas by day the roof generates heat, at night it then makes it possible to "save" the coolness. To do this, water to be cooled pours in a thin layer over the glassed surface of the roof-boiler. Through evaporation and radiation of heat into the night sky[1] the water temperature is lowered to 1-214° Celsius (to a higher temperature than the ambient air!) This is far from the limit of possible cooling. If the water is separated from the surrounding

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[1] The effective temperature of a cloudless night sky is much lower than zero. When the sky is cloud-free, the Earth emitting infrared rays into space rapidly loses heat.

structures with good insulation, then by this effect one can even obtain ice in summer if the sky is clear!

Thus, water cooled at night on the roof is collected in special tanks with good heat insulation. By day liquid is directed from them into radiators, which now serve no longer for heating but for cooling rooms. /21

Full-scale tests of this cooling system installed in a number of rooms of the Physico-Technical Institute proved its high effectiveness. Given the diurnal fluctuation in ambient air temperature of 15 degrees, the temperature of the air in a cooled room varied by less than a degree. At the same time in a control room not equipped with this cooling system the fluctuations in air temperature were 6-7 degrees.

Technical-economic calculations showed that the added construction costs of a home coming from installing the roof-boiler, pump and other uncomplicated equipment are only 15-20% of the initial costs. On the other hand, the subsequent advantage will not be slow in making itself felt: operating costs in this home compared to ordinary homes are two to three times less due to the savings in electric power and fuel. The time required to recover the capital outlays is 2-3 years. The fuel consumption for heating and providing hot water, per standard two-room home by means of solar energy, will be reduced to one-third. Also more than 5000 kWh of electrical power a year will be saved. And this is for a single cottage. But if they are built on a mass scale? Then by using solar energy for cooling and replacing with it only half of the fuel used in the rural rayons and small settlements of Central Asia, the savings will be expressed in an amazing figure -- 372 million rubles a year. For the seven regions of the USSR the annual economic benefit will be 2.4 billion rubles!

Tashkent solar power engineers proposed using the system of solar heating, hot water supply, and cooling of rooms they developed for equipping small apartments houses, administrative buildings, schools, sanitoria, and so on. Based on data obtained by the scientists, engineers at the Uzgiprosel'stroy institute drew up plans for heat supply and air conditioning for a kindergarten-nursery with 50 places. The operation of the system in two regimes is envisioned -- in summer and in winter, and modifications of a solar installation of a similar type were developed for four climatic zones. The construction of this unusual kindergarten-nursery is planned for the immediate future. /22

Not so much time will pass and the sun cottages will cease to be an unusual thing in the settlements of geologists, shepherds, cotton growers, ...

Intensive exploratory research also abroad is underway in this same direction. The French architect Jacques Michel, who together with Professor Felix Trombe, the director of the solar energy laboratory of the National Center for Scientific Research, the first French helio-house stated: "Solar heating is doubtless a prospect for the future. In developed industrial countries this will serve as an effective means of combatting environmental pollution."

The first house in France (105 m^2 of living space) with solar heating was built in the village of Shovansi-le-Chateau, department of Meuse (Lotharingia). Here a solar heating system somewhat differing from the one proposed by Uzbekistan scientists was used. The wall of the facade of this little house oriented stricted toward the south was made of four thick concrete panels painted a dark color for intense absorption of heat. The triple glass partition placed in front of them produces the thermal effect. The concrete panels have openings leading into the rooms of the house being warmed. The action of the system is based on the well known law of circulation of currents of cold and warm air. The latter, being lighter, rise, while with increasing cooling, on descending toward the floor, this current of air passes through an opening in the wall of the house into the "hothouse" where it is again heated. The heat accumulated during the day is transmitted to the living quarters at night. Nature itself went halfway to help the solar power engineers: it is precisely in winter when the Sun stands low over the horizon that the southern facade is best illuminated and therefore more strongly heated.

In summer this system serves an opposite function -- it cools the premises. With the windows open on the north side, from them /23 cool air will arrive and heated air will leave through the southern wall.

In the view of French specialists, this principle of solar heating is so simple that, as they anticipate, it will find wide use in mass housing construction.

Jacques Michel is studying the possibility of constructing an entire little resort city of these homes in the south of France, and also office buildings in Paris.

Even in a northern country like Great Britain, attention is being given to building "solar homes." A "solar school" has been built here based on scientists' plans. This two-story building is "heated" by the energy of the daytime star. Radiation is trapped by a so-called "solar wall" made of two series of glass panes.

Experimental solar homes have already been built in the United States and several other foreign countries. In our country, exploratory efforts by scientists in one more sunny republic are successfully underway in this area -- Turkmenia. Ashkhabad solar power engineers have proposed their systems of solar air conditio conditioning of buildings. Based on their plans, near Ashkhabad the republic's first solar home has been built, where scientists' calculations are being checked out.

It is not always possible and necessary to entirely run a home on solar energy. In this case, using solar energy one can solve individual problems, for example, produce only hot water. This can be done simply by taking one of the metal sections of a flat water heater (the roof-boiler is made up of these sections) in the solar cottage already familiar to us, set in into a special wooden frame and cover it from above with ordinary window glass. Now the box is placed in a courtyard by means of footings so that the solar rays at midday strike perpendicular to the surface of the glass (for the latitude of Tashkent the best angle of inclination to the horizon is 30°). Now our water heater is ready for use. In one day 60-80 liters of water at 60-70° Celsius can be obtained from each square meter. The efficiency of this device is 40-60% and it will serve reliably for the full 9 months -- spring, summer, and autumn. Its service life however is many /24
years.

After industry has mastered this solar water heater, its cost will be low. The device will pay for itself through fuel economies in just two-three seasons.

Depending on the user, solar heaters can be of various sizes. Calculations show that to supply a single individual with hot water it takes only a device with a surface area of 1-1.5 m^2. Simple solar boilers evidently will soon find wide use in households and also for hot water supply of kindergartens, Pioneer camps, showers in stadiums, baths, laundries, field camps [bivouacs], garages, dairy farms, and so on.

Water heaters of large sizes are best installed on roofs, as for example as been done in the central machine repair establishment of the builders of the Charvakskaya Hydroelectric Power Station. Here for already a considerable time a water heating device 82 m^2 in area has been functioning, installed according to the plans of the Physico-Technical Institute of the Uzbek SSR Academy of Sciences.

Solar water heaters have found wide use in several foreign countries. Judging from a report given at the UN Conference on New Sources of Energy in Rome in 1961, even then about 350,000 solar water heaters were operating in Tokyo. In the United States, mainly in the state of Florida, no fewer than 150,000 such devices have been in operation, while in this country a certain economic criterion was arrived at: roughly speaking, where a bright Sun shines for two-thirds of a year, the Sun must be vigorously utilized.

It should be expected that house owners will soon be able also to appraise solar cookers. Several kinds of designs of this equipment were already developed by scientists in Moscow and Tashkent.

A prototype of a solar cooker designed in the laboratory of the Power Institute imeni G.M. Krzhizhanovskiy consists of three parts: a mirror-reflector made of electrically polished aluminum, a tripod with a rotary mechanism, and a heat receiver. A cooking pot, tea kettle, frying pan, ... can serve as the latter. Even a flatiron can be heated in the focus of the emitter-collector. /25 Thus, in the desert even one's suit can be ironed in order to appear in the city as if arriving from a hotel in the capital. Every 10-12 min, it is true, the collector mirror must be rotated in order to correct the focus, following the movement of the Sun. Many years of tests in conditions of deserts, mountains, and other uninhabited localities in the southern parts of the country showed the high reliability of the solar cookers. It is equivalent in power to a hotplate of 800 W.

Staff members at the Physico-Technical Institute of the Uzbek SSR Academy of Sciences have proposed a solar cooker-umbrella. This apparatus is easily folded up, therefore it is conveniently carried along with shepherds, or geologists, and taken as part of their gear by scientists and prospectors on expeditions. When there is no need to prepare dinner, the cooker can be easily converted into a ... umbrella with a folding stool ready to protect the traveler from the scorching rays of the Sun or from showers, and even if the tarpaulin is folded up against the handle of the reflector -- you get a tent or a night's lodging.

The industrial production of water heaters and solar cookers is projected for the Ninth Five Year Plan. To built this equipment, the countries first plant of solar equipment will be erected in Bukhara. It is expected that this enterprise will master the yearly output of solar water heaters with a total area of 50,000 m^2 and 25,000 solar cookers.

Next in line for introduction into use are other innovations of solar power engineering on which scientists are laboring. Thus, in the Bukhara Pedagogy Institute and in the Physico-Technical Institute of the republic's Academy of Sciences, already an everyday solar refrigerator has been developed and tested, using radiant energy.

The advantages of the solar refrigerator speak for themselves: it does without moving mechanisms, it does not need electric power and it does not require constant care.

And here is a solar drier for fruit that is recommended by the Physico-Technical Institute of the Uzbek SSR Academy of Sciences for acceptance in daily practice. Its design is very simple: the device consists of a wooden glassed frame, lined within with a blackened corrugated metal sheet half a millimeter in thickness. Boards or plywood are nailed to the frame at the bottom. Air driven by the fan through the frame is heated by the blackened metal sheet, and then on being heated to 60-80° this air enters the chamber where the fruit are spread out to be dried. Taking moisture from them, the air exits to the outside. /26

Extended experimental studies showed that drying in the solar device proceeds several times faster compared with drying in air by the usual methods.

The possibilities of using solar driers can be set down in a long list -- these economical units are needed for both vegetables and grains, and silkworm cocoons and tobacco, ...

The operation also of a device intended for steaming reinforced concrete structural members is based on the "hot box" principle: this device was also proposed for introduction by scientists at the Physico-Technical Institute of the republic's Academy of Sciences. The steaming chamber into which a cart bearing reinforced concrete members is rolled is made hermetic. The southern inclined wall of the chamber has double glassing. Penetrating through the glass, radiant energy heats the chamber and the reinforced concrete members in it. This requires only a day. It was shown that drying is accelerated by more than 10 times.

The Sun can be successfully used in heating water in swimming pools, for thawing soil in the gold-fields of the North, for driving various mechanisms, and for performing the most diverse kinds of work.

Today domestic solar power engineering has entered the period of a new upsurge in its research. For the first time in the country, during the Ninth Five Year Plan these studies will be carried out under a well-coordinated plan confirmed by the State Committee of the USSR Council of Ministers on Science and Technology. This will permit unifying and concentrating the efforts of scientists at many institutes.

Tashkent has become one of the country's leading centers of solar power engineering research. This is understandable, in fact Uzbekistan is one of the sunniest republics of the country. While the Sun shines on 1654 hours a year in Moscow, it shines 2870 hours in Tashkent, 2916 hours in Samarkand, 3043 hours in Termez, and so on. /27

The rich flux of free energy streaming from the heavens and the great research efforts carried out afford hope that the city of the Sun will become a reality in the not distant future.

The Sun Waters the Desert

In drying up the desert, it turns out the Sun can also water it. The point is that in the interior of deserts there are large reserves of mineral water unsuitable for drinking. Using solar energy it can be converted into drinking water.

Already for several years a solar fresh-water still has operated in the center of the Karakumy. Shepherds of the Bakharden Turkmen sovkhoz bring their flocks of Karakul sheep here for watering. Every day more than three cubic meters of water accumulates beneath the walls of the fresh-water still -- enough to water 500 sheep. Here the water is made fresh under a glass surface having an area of about 600 m^2. Reinforced concrete troughs are covered with this glass. In them solar rays heat the brackish water. It evaporates as in an ordinary hothouse, and then settles on the inner surface of the glass panes which are placed at an angle. This makes it possible for the cooled moisture to trickle into gutters, and from them -- into a concrete fresh-water reservoir.

Brackish water is supplied beneath the glass panes of the fresh-water stills also by means of solar energy. Parabolic-cylindrical mirror reflectors collect solar rays into a bundle and direct it at silicon batteries. Light is converted into electric current. The power of the unit is small -- only 450 W. But it is enough to drive a pump which pumps the brackish water from the well.

The installation is fully automated. Shepherds do not have to either turn it on or off. Everything is done automatically, in response to the rising and setting of the Sun. The automatic devices also keep track of the Sun's movement across the sky, suitably rotating the solar ray reflectors. Without human participation the pump is also switched off if the concrete vessel is /28 filled, and switched on when it becomes partially emptied. "The extra" energy goes to trickle charging of the collectors. Their energy is used in "hunting" for the Sun and in switching the unit from evening position to morning. Only twice a year does a specialist have to inspect the solar pump for preventive maintenance and lubrication. Its operating life is measured in the decades.

The cost of a cubic meter of fresh water obtained in this way is not more than 2 rubles. And in fact, in several desert areas it costs much more -- tens of rubles per cubic meter. Calculations show that if the fresh water source is 30 km away, it is cheaper to build a fresh-water still even with the installation of expensive silicon batteries.

Turkmenia's experience was used also in Uzbekistan. According to plans of scientists at the Physico-Technical Institute of the republic's Academy of Sciences and the Bukhara Pedagogic Institute, a large fresh-water still was constructed in Kyzylkumy. It provides fresh water for the central farmstead of the Shafrikan Karakul-raising Sovkhoz. Before drinking water was delivered here from 50-60 km away. The local Baymurat-Kuduk well gave only bitter-brackish high-sulfur water. It contained up to 12 g salt per liter. Today this moisture brought in by belt water lift is sent to dozens of "boilers" -- reinforced concrete troughs covered on top with glass. The installation began to provide the farm everyday with about 4 tons of cheap drinking water. Operation of this fresh-water still showed that it runs well even in winter.

In building the device at the Shafrikan Sovkhoz, Uzbek scientists not only drew on the experience of their neighboring republic, but even went further. Specifically, two devices were built here. One is made of improved reinforced concrete troughs of the Turkmen type, while the other is an original, inclined-stepped trough.

Specialists in agriculture in Bukharskaya Oblast gave high marks to the solar fresh-water still in the Shafrikan Sovkhoz. Already in the immediate future it is projected to built fresh-water stills in several other livestock farms in the desert. The need for fresh water in Kyzylkumy is great. Livestock raisers are trying now to lay out orchards and build gardens on the sands, /29
and fresh water is also necessary for this.

Uzbek scientists drew up a plan also for a mobile fresh-water still for shepherds. In size and even in appearance it looks like a small suitcase. The capacity of this "solar samovar" is 10 liters of fresh water a day.

What has come from the ubiquitous use in arid regions of stationary and portable solar fresh-water stills? Calculations show the following: this practice will increase the territory of pastureland for graising of karakul sheep in our country 30-50% and will provide watering for flocks where previously livestock raisers had never gone owing to the absence of fresh water. This is a contributing coming from solar power engineers and scientists in carrying out the program of intensive growth of animal husbandry in our country projected by the Directives of the 24th Congress of the CPSU.

Fresh-water stills are necessary not only to shepherds, but also to geologists, builders, and expeditions of scientists -- to all who will conquer the desert, and will place its riches at the service of Soviet man.

The conversion of mineralized water into fresh water is only one stage in the extraction of water in the desert. Here above all moisture must be raised from the interior to the Earth's surface. As we have already stated, in the Bakharden Turkmen Sovkhoz this is done by means of the Sun: its golden rays are converted into electric power by a semiconductor battery. Silicon necessary to make these batteries thus far is very expensive. This is holding back the mass introduction of the pumps with semiconductor converters of solar energy. But silicon pumps are not the only way of making the Sun pump water.

Another kind of drive has been developed in the Physico-Technical Institute of the Uzbekistan Academy of Sciences. It consists of the solar energy collector already familar to us, 5 m in diameter, and a Stirling engine. The device is marked by simplicity, reliability, and low cost. It can lift up to 4-5 m^3 of water daily from a well as deep as 20 m. In a day this pump can water a flock of 2500 sheep.

The problem of building an effective design of a solar water lift is so urgent that in 1971 the USSR Ministry of Agriculture, /30 the USSR Ministry of Land Reclamation and Water Resource Management, and the All-Union Council of Scientific-Technical Societies announced a union-wide contest for its best design. The economic benefit from introducing solar water lifts will be great.

But the Sun is capable of watering man not only on Earth. Our star will come to the service of men also on other planets. It has been reported in the foreign press that American scientists built a device that can obtain water by solar energy on the Moon, where water is to found in the rocks.

"Canning" ... Rays

Quite recently researchers in Antarctica discovered a puzzling lake located in a mountain valley in Victoria Land, not far from New Zealand and American scientific stations. The lake, which was given the feminine name Wanda, is covered with a thick layer of ice; however, at its very bottom, 60 m down, the water is heated to 26° Celsius.

New Zealand scientists concluded that heat in the bottom waters of the lake arrives from above -- from the Sun. The researchers measured the amount of solar energy penetrating through the ice layers and estimated the value of the radiation that can reach the bottom layer. Heat losses proved to be small, though the Sun heats the waters of the lake for a very short time -- only during the short Antarctic summer.

The scientists explained the effect they found by two factors. The main factor is the increased density of the lowest, salt-saturated layer of water which makes it virtually still and prevents heat losses due to the convection. The second important factor is the exceptional purity of the water in the lake. This enables sunlight to penetrate quite deeply.

This discovery then was an even greater sensation to solar power engineers. In fact natural solar energy collectors had been discovered! Solar power engineers have long tried to build these devices in research proving grounds. But the construction /31 of solar collectors from which the energy stored for the future could be tapped for any time suitable for man proved to be a highly complicated matter.

Investigations have been conducted in the Physico-Technical Institute showing that salt pans are highly promising for the accumulation of solar energy. These are bodies of water filled with layers of salt solutions at different concentrations. The deeper the layer, the denser the solution. The most dense and heaviest layer is at the bottom. It is also heated most of all. The water temperature in it is 90-95° Celsius. The coldest is the uppermost layer of the solution. Since the density of the solution layers differ, they do not mix. Heat losses from this pan are very slight.

A simple and inexpensive method of constructing these pans was also proposed. They are located most conveniently along the shore of the sea or lake. Here a pit is dug, the bottom is covered with a layer of salt seawater, then it is evaporated to the required salt concentration. The same is done with the second layer, and so forth. Using seawater eliminates the problem of salt, of which a great deal is needed to build these solar accumulators. Tashkent solar power engineers also looked at different variants of the collection of heat from the pans. To do this, a system of pipes must be laid along their bottom; through these pipes cold water or a low-boiling liquid for thermal machines can be passed. The second approach is to directly remove from the bottom a heated solution, which then is passed through an external heat exchanger and returned back to the pan. Experiments showed that owing to the different density of the solutions their mixing does not take place as this is done. However, under this method of removing heat it is best if the lowest heated layer be separated with a transparent film. Because of this, the temperature of the bottom layer will be 5° higher than under the nonfilm variant. An installation with a film separating the lower layer from the rest of the water in the pan will reach the working regime faster and the heat losses in it will be smaller. Also, the film will make it possible to regulate the flow rate of the coolant in the circulation loopes and ensure the optimal regime of heat removal /32 from the pan. From the energy point of view, this variant can also be assumed to be most successful and advantageous.

Small salt pans owing to the rapid accumulation of solar energy ensure users with hot water throughout the full day.

Installations with pans 1 m or more in depth make it possible to conserve solar energy that can be used in heating homes, providing them with hot water, and for air conditioning. In a complex with an absorption type refrigerator, solar salt pans can form ice, and when used in conjunction with freon-ejector jet pumps (using the kinetic energy of freon to mix the cooled air) they can be used in air conditioning.

One more possible approach to conserving solar heat has been laid out by co-workers at the Physico-Technical Institute of the Uzbek SSR Academy of Sciences in one of the sovkhozes of the Golodnaya Steppe, where they worked on harvesting cotton. The attention of scientist was drawn to heavy-duty vertical-drainage pumps. Could not these pumps be placed to the service of solar power engineering? There are also no small number of effective methods of heating water by means of radiant energy. But how can the heat be conserved?... Calculations showed the following: porous sandy horizons in which hot water can be lowered via pipes are excellent heat collectors.

Here it is very important that the pumped water not be mixed with the groundwater and that the artesian wells not be entrained. Why not then construct walls against this beneath the Earth! This would prove to be very costly. But here is the drainage well ... The hydrological regime it produced proved to be ideal for solar energy collectors, it was only necessary to finish something. And then ...

Through four wells drilled at the corners of a tract in the center of which there was a drainage well hot water was pumped. Being lighter, it forms an isolated lens at the surface of the brackish water! Mixing does not occur. Under the conditions of vertical drainage there is no danger of extraneous artesian currents appearing that could carry away the heat. A distinguishing feature of this method of storing solar energy is its cheapness.

Systems of vertical drainage exist or are being built in many /33
rural areas of Central Asia. It is very important that the applications of wells of this system for storing solar energy not interfere with their use also for their direct function. Just in the sector of a single well, as shown by calculations, enough heat can be stored as would be given by burning up 10,000 tons of coal.

Energy from solar collectors during the cold time of the year is used for heating the hothouses, apartment houses and for various household purposes. If the so-called heat pumps are used, the area of application of this energy is much broader.

The operating principle also of solar hothouses is based on the accumulation of solar energy. In them radiant energy is

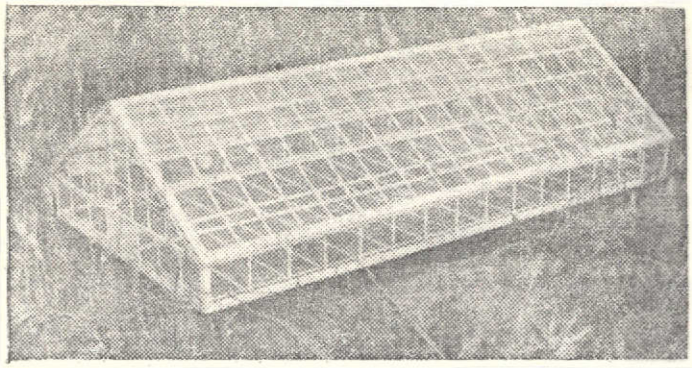

Fig. 4. Mockup of solar hothouse. A solar collector is beneath its soil, providing this structure with heat during cold periods.

accumulated in a special chamber where different heat-absorbing materials are placed -- slag-concrete, concrete, brick ... Days, through this chamber sun-heated air is passed. During this time "charging" of unique collectors with heat takes place. But at night they "discharge." Heat is transferred to the current of air circulating in the solar hothouse. Thus, in it around the clock normal temperatures are maintained.

Warming hothouses by this method makes it possible to save /34
large amounts of fuel. Only on very cold and overcast days is it necessary to resort to heating with gas burners or electricity in order to maintain the temperature conditions. But the necessity of using expensive boiler arrangements supplying heat to the hothouse pavilions disappears altogether.

Several solar hothouses have been built in Uzbekistan -- in Kashkadar'inskaya and Bukharskaya oblast. The first hothouse was built in the Avrora virgin lands sovkhoz. It occupies 2000 m^2. Solar energy is accumulated here with crushed rock and sand with which boxes are filled. The heat-accumulating block is placed vertically. In practice it was found that this is not at all convenient. The block takes up much space within the hothouse and does not make it possible to adequately illuminate the room. A way out was found by staff members at the Physico-Technical Institute of the Uzbekistan Academy of Sciences. They developed a variant of solar hothouses with horizontally arranged accumulating elements. By this technique, air is circulated with a forced-draft centrifugal fan.

The use of horizontal solar collectors in hothouse projects as shown by calculations makes it possible to save upwards of two-thirds of the heat consumed. Outlays in electric power used in providing forced ventilation amount to only one-tenth of the cost of the heat delivered by the Sun. And one more important factor is that there is no overheating in solar hothouses, while the solar collectors arranged beneath the hothouse warm the soil well. This provides favorable conditions for plant growth. Today Tashkent engineers have developed a standard plan for solar hothouses.

Solar collectors are capable also of warming rural cottages. Imagine three Dutch ovens joined together. Each of them is filled with cobblestones which by day "soak up" heat from the air circulating in the room, and at night give it up.

In the cottage are two unusual thermal walls which divide the little place into three parts. These walls also divide up a glassed-in veranda which serves as a "trap" for the sunlight. /35

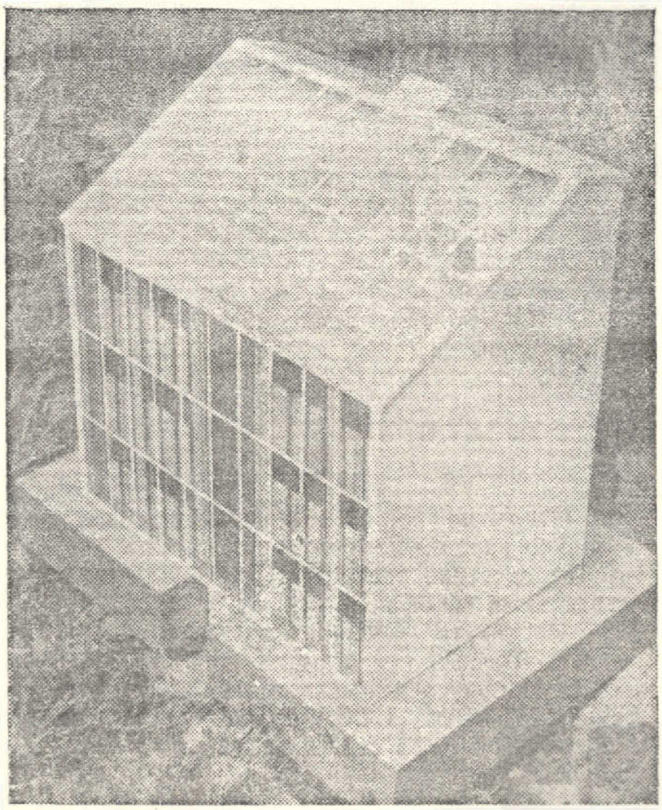

Fig. 5. Mockup of three-story solar home with greenhouse in attic. In the center of the building is a shaft containing heat-absorbing material -- the solar collector.

The second "trap" is a two-layer sloping roof. On the sunlit side it is made of two layers of glass between which another corrugated glass sheet is inserted. Therefore the glass is a kind of air heater. Next the thermal flow by day is directed to solar collectors. They are capable of storing up the amount of energy that is needed to warm the house for two days. In the event of prolonged spells of bad /36 weather of course standby heating systems -- gas or electrical -- must be switched on. By means of solar collectors it is possible to save 60% of the fuel. In summer these collectors can be used for the opposite purpose -- for cooling.

Tashkent solar power engineers also proposed plans for a three-story house with a hothouse in the attic. Here the solar energy collector is a shaft filled with cobblestones. It ascends through all stories of the house and its center. The attic room where the hothouse is located serves at the "trap" of solar rays. From here warm air is sent to the shaft containing the stones. At night then circulation of air is provided through this collector and through all the rooms of the house.

Scientists are still looking for new ways of storing solar energy. Various chemicals are being investigated that could be capable after giving off thermal energy again accumulating it with their initial capacity.

The scales in which solar power engineering is introduced into the national economy will depend on the effective solution of this problem, to a great extent.

Effect of Discontinuous [Pulsed] Rays

The discovery was unexpected. It came from the just-formed direction of research -- photoenergetics of plants. Everything happened at the beginning of the 1960's in the polar regions at the experimental base of the Institute of Plant Physiology of the USSR Academy of Sciences. At that time, close to the Apatity station where now are situated the buildings of the academic city of the Kola Branch of the USSR Academy of Sciences Moscow professor A.A. Shakov together with his laboratory assistant [illegible].A. Stankov investigated the effect of concentrated sunlight on processes in plants with the Sun in the sky for the entire 24-hour day. The experimenter used the Bukhman reflector well known at that time among solar power engineers. The problem was to study ways of increasing the productivity of plants in the polar region where /37
the Sun is always low over the horizon and its rays are weaker than in the south. The investigators assumed that they would be able to achieve certain results by intensifying the process of photosynthesis.

Later, Professor Aleksandr Aleksandrovich Shakov wrote about how in science the investigation of a problem in one direction not infrequently leads to its solution in another direction that is sometimes more general and more important than the original area. Thus there was born the problem of irradiating plants with pulsed concentrated sunlight.

Both dry as well as moistened seeds of barley and wheat were irradiated, as well as sprouts of these plants in different phases of development. Then experiments were conducted with potato tubers. The results amazed the investigators: not only was the germination of the seeds improved, but the plants themselves were found to be more lush, better developed, and yields rose 15-20%. From seeds treated with bunched light grain of improved quality was harvested. The grains were heavier and larger than the control grains and contained more protein.

The first scientific publication of the discovery of the light-pulsed effect appeared in the literature in 1962. It served as the basis for the development of a new scientific direction -- photoenergetics of plants.

Then also began experiments on the use of pulsed concentrated sunlight in Kazakhstan. Here the object of the investigations were mainly vegetables. The results of many years of investigations showed the following: the boost in the early yield of cucumbers was 20-30%, and 70% for tomatoes. When the yields were compared for sown crops and for crops under film covering, the advantage of the latter variant was very large. Thus, the yield of cucumbers of early-maturing varieties (from plants grown from irradiated seeds) beneath film exceeded the yield from sown crops by an average of five times. The yield beneath film was 400-500 quintals per hectare. It should be noted that beneath the film cover the relative increment in the early-maturing harvest is less than in the sown crop. But the high absolute yield of the early harvest of cucumbers owing to presowing seed irradiation ensures a great advantage. The cultivation of cucumbers from irradiated seeds beneath plant covering can provide the area near Alma-Ata a net income of up to 4000 rubles per hectare. In the /38
Moscow area this figure is somewhat less -- 3000 rubles per hectare.

Experiments on pre-sowing irradiation of potato tubers in Kazakhstan, Belorussian and Moldavia also proved affirmative. In these experiments a one-hour irradiation yielded the same results as the month-long cultivation in light adopted in the agrotechnics of potatoes.

Also proving effective was the action of light-pulsed irradiation in the growing of melons and watermelons. Not only did the yield rise but the production of seeds of new reproduction rose 5-10%. This is particularly vital for seed-growing of melons and gourds.

The use of light-pulsed irradiation is promising in beet-growing. In the Kuban' four years of field experiments showed that it is also possible in this way to raise the sugar content of beet roots 0.5%; in the Ukraine three years of growing experiments yielded an even greater benefit -- 1-1.2% increase in sugar content in beets. If it is possible overall by means of the light-pulses technique to raise the sugar content for the Ukraine only by 1%, then in one year this would mean an additional income of about 300 million rubles.

In 1964 scientific efforts to explain the nature of the action of the unique solar light spot on the cotton plant began in Uzbekistan. It was found possible to drawn one valuable conclusion at least -- pulsed concentrated beams of radiant energy are capable of boosting the yields of this valuable technical crop.

How were the experiments conducted? By means of a mirror solar ray concentrator operating in the pulsed mode, cotton plant seeds were irradiated. This regime proved to be necessary not only from the standpoint of preventing the scorching of seeds by the powerful flux of solar energy, but also from the standpoint of the absorption of radiant energy by the seeds -- the radiant energy reached the seeds in specific portions. In the experiments were the irradiation was carried out by the continous flux method, no improvement was observed. As a result of these experiments it turned out that the cotton yield climbed 12-15%.

Efforts in this direction were begun for the first time by scientists at the Tashkent Agricultural Institute. At first the experiments were carried out under laboratory conditions: observations were made of the development of irradiated cotton in the so-called vegetative vessels. Then the experiments were transferred into the fields. /39

Bukhara became the republic's second center of this scientific direction. Here scientists from the local pedagogic institute are carrying out experiments jointly with the oblast agricultural test station. During a period of years they have achieved a marked increment in cotton yields. Compared with the control planted in 1971, the improvement was 14%.

Scientists of the Uzbekistan used irradiation with pulsed concentrated light also in growing other farm crops. Thus, by this method the Bukhara researchers were able to boost the yield of cucumbers, onions, radishes and carrots 10 to 30%.

By irradiation with pulsed concentrated sunlight scientists of the Microbiology Department of the Uzbekistan Academy of Sciences were able to accelerate the growth of the microscopic algae Chlorella 30%. This aquatic plant is being used, on the recommendation of Uzbek biologists, in livestock farms of the republic as a vitamin addition to feed. The green algae can boost the cattle weight gain by an average of 20%.

Investigation has proved that the "magic ray" can not only influence the intensive growth of Chlorella, but also boost its carotene content, from which vitamin A is synthesized in the organism -- by 2-2.5 times; young animals need vitamin A particularly acutely. The radiation increases also the protein content in Chlorella 10%.

What then in the miracle-working power of the unusual solar rays? Even until quite recently it was assumed to be beyond question that the transformation of solar energy into chemical energy occurs in plants only in one way -- by photosynthesis. However, as shown by investigations of Soviet scientists, there is also another way, when solar energy is used by nonphotosynthesizing organs -- seeds, tubers, and even pollen. Often they do not contain the green pigment known to all -- chlorophyll, an obligatory component of the photosynthetic process.

Now, irradiation of plants with pulsed sunlight can be represented as a continuous powerful flux -- a "cluster" of photons. It is capable of charging additional energy into the irradiated objects, and in particular, causing photophysical and biochemical changes in seeds. When molecules in plant cells absorb concentrated portions of light, as shown by results of recent investigations, free radicals marked by especially high chemical activity are formed therein. During seed sprouting time, the energy of free radicals is transferred to the plant tissues, which causes their accelerated growth.. Here there are changes in metabolism in chloroplasts, mitochondria, and other cell particles responsible for transformation of energy. /40

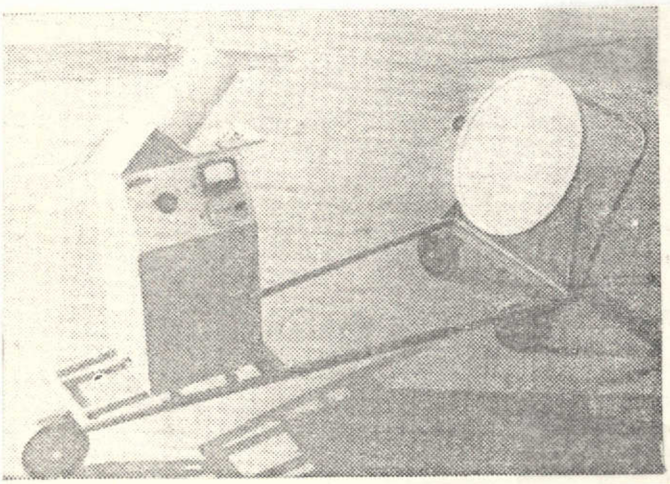

Fig. 6. Device for irradiating biological materials with pulsed sunlight, IKSS-1M -- a joint development of the Physico-Technical Institute of the Uzbek SSR Academy of Sciences and the Institute of Applied Physics of the Moldavian SSR Academy of Sciences.

As a result of the action of the "miracle" ray on seeds and plants, various physical processes are stimulated; energy exchange is enhanced; the /41 utilization of solar energy for synthesis of organic compounds becomes more complete. Observations showed that in seeds receiving a "charge" from sunlight, germination and sprouting energy rose. These seeds yield well developing and more productive plants. Much research effort is underway in the new direction, and it is expected that this will lead to important discoveries.

One such discovery was already made by A.A. Shakov and co-workers. It was found that pulsed concentrated sunlight has a mutagenic effect -- it changes plant heredity.

Today it is already clear that breeders and geneticists have obtained a scientific method capable of becoming a powerful tool in deriving new varieties of farm crops. Thus, in the course of experiments at the Tashkent Agricultural Institute, changes were noted in the structure of cotton bushes, whose seeds had been irradiated with doses of extra-high concentration.

This means that solar rays are the key in the hands of breeders. And this direction has been recognized as most important by participants of a conference of specialists held at the Uzbek SSR Academy of Sciences.

By means of this key, already our country has obtained promising varieties of wheat, corn, soybean, tomatoes... They exhibit higher yields and numerous improved economic qualities. Thus, the sugar content was raised in sugar beets; the protein content -- in wheat in soybeans; the ascorbic acid and sugar content in tomatoes; the fat content in soybeans; the alkaloids content in medicial plants; and the carotene and protein content in the algae Chlorella.

The first mutagenic varieties of farm crops obtained by irradiating with discontinuous sunlight are now being tested at state variety-testing plots. In Moldavia and the southwestern oblasts of the Ukraine "light" wheat is being reproduced at an accelerated pace in production and is under testing: it is a mutant of the famed variety Bezostay 1. The newcomer differs from its predecessor by its excellent winter resistance and drought resistance and by its strong and thick, nonlodging stems. The grain of "light" wheat contains 1.9% more protein than Bezostay 1. In /42
terms of yield, the new wheat variety exceeds its predecessor by 5-6 quintals grain per hectare. The "light" wheat strain in the conditions of Moldavia is virtually unaffected by brown rust.

By the same method, mutant substrains of high-productivity corn have been breed at the Kishinev Agricultural Institute. One of the substrains after crossing gaven an increment of dry grain amounting to 12.9 quintals per hectare, while the standard harvest was 43.2 quintals per hectare, on the average. In these experiments pollen and underdeveloped panicles of the corn underwent pulsed-light irradiation. By irradiating the generative parts of poplars, staff members at the Kazakh Agricultural Institute also boosted the effectiveness of hybridization and obtained valuable heterosic seedlings.

Soviet biologists are expanding their study of the effect on plant heredity of pulsed concentrated sunlight. More and more new farm crops are being treated with it. Investigations in this area will be of no small practical benefit in the future. But even today one can speak of the necessity of introducing into practice the first results of this scientific undertaking. Clearly, it is already time in the republics of Central Asia, in Kazakhstan, in Moldavia, in the southern oblasts of the Russian Federation and in the Ukraine, to organize at farm test stations units for presowing pulsed-light irradiation of seeds of vegetable crops and to distribute them to vegetable farms. This would provide them with improved varietal seeds. These support stations, utilizing more and more new scientific data, subsequently will expand the varieties of irradiated plants.

Today for experiments on irradiating biological materials with
pulsed concentrated sunlight, improved equipment has been designed.
Jointly with the Institute of Applied Physics of the Moldavian
SSR Academy of Sciences the Physico-Technical Institute of the
Uzbek SSR Academy of Sciences built the device IKSS-1M; over a wide
range it is capable of regulating the degree of concentration and
the frequency of light pulses. Its intensity in this equipment
is 140 W. At bigger device capable of a light intensity of /43
1200 W was designed by Dzhabbir Alavutdinov, a scientific co-
worker of the Physico-Technical Institute of the Uzbek Academy of
Sciences. With a tenfold concentration of sunlight, the device
is capable of irradiating seeds of cotton plants and other plants
at a frequency of 60 pulses per minute. A parabolic-cylindrical
collector with a rotating network cylinder at the focus was de-
veloped for seed irradiation by M. Kakhkharov. One could have
become familiar with this new equipment at an exhibition of solar
equipment set up at the All-Union Palace of the National Economy
of the Uzbek SSR during the First All-Union Scientific Research
Conference on Renewable Energy Sources held in Tashkent late in
1972. By the way, a special section of plant photoenergetics was
functioning at this conference: more than 30 papers were read
at this section.

Today persons in Moscow, Kazakhstan, Moldavia, the polar areas, in the Ukraine, and in other scientific centers of the country are studying the biological action of clustered, discontinuous sunlight.

Pulsed light irradiation is one of the means used by science of influencing plant heredity. However, compared with radioactive radiation and chemical mutagens widely accessible to and harmless to man, it is marked by simplicity and low cost in use, and the main point is that it is closest to the actual nature of plants. A broad field of activity and a tempting prospect has opened before geneticists and plant breeders. By modifying the spectral composition and energy of photopulses, the experimenters can achieve very substantial results in developing highly productive plant varieties.

Efforts are still underway in one more important direction. It turns out that if one rationally utilizes solar radiation, the limit to the cultivation of the most valuable varieties of cotton -- fine-fibered (marked by an increased thermophilicity) -- can be shifted northward 500 km.

But how is this possible? The amount of solar radiation de-
pends on the following factors: geographical attitude of the
location, time of year, angle of inclination of sunlight to the
horizon, orientation of the field, and also the transparency of /44
the atmosphere. In Uzbekistan the maximum amount of solar radia-
tion per square meter of the horizontal surface during the entire
growing period of cotton occurs at the latitude of 37° (this is in

the area of Termez). If this radiation is taken as 100%, the amount of solar radiation falling during the entire growing period of cotton per square meter of horizontal surface for the latitude of 40° is 99%, while it is 98% for the latitude 42° (this is the area of Tashkent). Thus, in the more northerly oblasts the amount of solar radiation is appreciably reduced.

But what is the effect of field orientation? Even with these small angles of inclination to the horizon (such as 5-10°), the difference, as measurements show, becomes very sizable. Thus, for fields with a southerly, southeasterly, and southwesterly exposure the amount of total solar radiation is 5-10% greater than the amount of radiation falling on a field with a northerly, northeasterly, and northwesterly exposure.

Therefore different amounts of solar energy can be obtained even by neighboring fields lying on the same latitude. The whole issue lies in their orientation toward the points of the compass. In fact we know that most field do not lie horizontally.

Calculations show that the amount of solar radiation arriving on cotton plantations with an inclination of 5-10° toward the south for any latitude in the area of Uzbekistan, Tadzhikistan, and Turkmenia, is not less than on horizontal field tracts at the latitude of 37°. It follows that with a so southerly exposure and an angle of inclination of the surface of the horizon within the limits 5-10°, fine-fibered cotton can be cultivated in any cotton-growing republic of the land. But in fields with a southeasterly and southwesterly exposure, fine-grained varieties can be sown only up to the latitude of 40°.

On the other hand, it is not any oriented field in southern oblasts of the country where at the present time fine-fibered cotton is sown that can give the anticipated results. Here the amount of solar radiation falling on a field with a northerly, northeasterly or northwesterly exposure clearly is inadequate for heat-loving varieties. Medium-fibered cotton varieties must be /45
sown in these fields. They corresponds most closely to these plantations in their radiation regime.

It is by now obvious that for a proper arrangement of sowings of cotton varieties differing in thermophilicity, radiation maps of plantations must be compiled. This will make it possible, depending on the amount of total solar radiation in the growing period, to select for sowing the corresponding cotton varieties, and to advance its most valuable varieties into the more northerly zones of cultivation.

A no less important problem linked to the radiation regime is the influence of the form and orientation of field furrows on the schedules of cotton plantings. Calculations made at the Physico-Technical Institute of the Uzbek SSR Academy of Sciences showed that when the slope of furrows is 30-35° with southerly, southeasterly, or southwesterly exposure, the radiation balance during the spring period rises compared with the horizontal surface by nearly 40%, while in winter by even more than 80%. As a result, the daytime temperature of the furrowed soil during the spring period rises by an average of 7-8° in temperature in the horizontal fields. This means there is the opportunity of beginning the sowing of cotton more than 10-15 days earlier than the customary date. Therefore (when the former period of defoliation is retained -- chemical removal of leaves before machine harvesting of the raw cotton), by roughly the same number of days the developmental time of cotton can be increased. As a result, immature cotton bolls are able to develop normally by the beginning of defoliation and thus markedly increase cotton yields. In addition, early maturation of cotton plays an extremely vital role in improving the grade of raw cotton (with the onset of rainy periods its grade deteriorates sharply).

Hence follows a practical recommendation: 15-20 days before the usual beginning of sowing the fields are to be furrowed and cotton planting is to be carried out not on an even horizontal field as is being done at present, but on a previously prepared furrow with a southerly, southeasterly or southwesterly exposure. Doubtless, the period by which sowing is to be anticipated by this /46 method is not the same for all cotton-growing republics and oblasts. Therefore, for each zone the optimal planting schedules of cotton seeds must be studied and determined experimentally based on the proposed method of presowing furrowing.

It appears to us that compiling radiation maps of fields and the furrowing method of sowing would yield benefits also in the cultivation of other farm crops.

Yet another problem in agriculture -- control of pests of cultivated plants -- can also be solved by means of solar power engineering. Specialists at the Physico-Technical Institute of the Uzbekistan Academy of Sciences jointly with staff members of the Institute of Plant Protection of this republic have labored to build light traps. They are powered with current generated by a solar energy converter. The solar energy is stored during the dark period of the day by means of ordinary collectors.

The advantage of solar light traps is that they can be used even in places distant from power transmission lines. Making practical use of these light traps, which utilize their distinguishing feature to wipe out insect pests -- insects fly toward light at night -- is of high national-economic value.

Either increasing the effectiveness of the photosynthetic process or finding ways of the nonphotosynthetic action on increasing plant yields, and many other methods of the best utilization of solar energy in agriculture, is to be expected, will bear fruit.

Both Metallurgical Worker and Welder

"In 4 min and 40 sec the experiment ended -- in a thick 12-mm steel armored plate there gaped a hole a good half meter wide. From the lower edge of the scorched hole there hung, just like icy counterparts, metal 'icicles.'" Thus is described the results of French scientists reported in the West Germany magazine Der Spiegel. The experiment was held in Odeille, in the south of France, where the world's biggest solar furnace was built. /47
Here on a eight-stepped terrace solar power engineers arranged 63 sliding flat mirrors with an area of 45 m^2 each.

By means of photocells the mirrors are constantly oriented towards the Sun. In fact the entire system directs solar rays at an enormous parabolic mirror located opposite the terrace. Its height is 45 m and its area is nearly that of a football field.

This colossal convex mirror was also constructed by the French scientists using individual mirrors with slight curvature. The mosaic of nearly 9000 mirrors is mounted so that solar rays are collected at a focusing point 18 m from the gigantic mirror. Thus far it has been possible to reach temperature of 3300° at the focus. However, scientists expect that this is far from the limit. The energy concentrated by this colossal mirror is being used for fusing metals and fabricating ultra-high pure materials. This is being done in a special tower. Its two steel doors are usually closed and are flung open only to prepare materials for fusion. A special system of water circulation protects the tower against overheating.

This unique solar furnace belongs to the National Center of Scientific Research, which spent 10 years in its designing and building. The idea of building this enormous furnace belongs to Professor Felix Trombe, who even during the first postwar years was able to use mirrors of old captured German antiaircraft searchlights in the fusion of metals. At that time, temperatures of 3000° were achieved in a solar furnace built in Meaux, near Paris. With this much heat, the most refractory metals fused in a few seconds. Carbon sublimation also occurred. A sensation was raised by the synthesis in Meaux of nitric acid from nitrogen and oxygen contained directly in the air. But the Sun was not strong long enough in the Paris area, therefore further investigations had to be transferred to the eastern Pyrenees (this area is in the same latitude as northern Uzbekistan). Here scientists obtained access to the old castle of Mont-Louis, where several solar furnaces were built, including a large one. Their operating /48
experience then was used in construction of the pride of the

French scientists -- the giant solar furnace near Odeille, where the Sun shines 2750 hours a year, that is, a full thousand hours more than near Paris. Incidentally, in the Karakalpak city of Chimbay located at the same latitude as Odeille, the Sun shines for 2928 hours a year.

During fusions in the solar furnace contamination of the materials used is avoided. This makes it possible to produce a pure product with desired composition in a different gaseous medium or in high vacuum. In fact, "solar fusion" can be conducted even in a hermetic vessel and beneath an airtight hood, the only requirement is that they be transparent to light. A beam of sunlight in this case heats only the substance to be fused, while in electric furnaces fusion takes place in crucibles in direct contact with electrodes. But during solar fusion, "sterile fire" acts on a relatively small volume of the material being processed. Even at a short distance from the focusing spot the temperatures are somewhat lower and this is an important advantage: because of this, the molten materials are prevented from undesirable chemical reactions with the material in the reservoirs.

The laboratory at Odeille, as reported by Der Spiegel, uses solar energy in making extra-high purity materials. For example, the French scientists removed by means of fusion impurities disturbing the purity of metals and have made high grade quartz.

French atomic scientists also utilize this giant solar furnace. The high temperature of pointwise and instantaneous action serves them in simulation of explosions of atomic bombs. Thus they test the heat resistance of paints, plastics and other materials. Also underway at Odeille are tests of materials used in the missile industry and in nuclear power stations; here new valuable and pure alloys for other areas of science and technology are being produced.

High-temperature studies using solar energy are also being conducted by scientists of the United States and other countries. Solar power engineers of Armenia, Turkmenia, the Ukraine and Uzbekistan are working on designing solar furnaces. /49 Thus, a high-temperature device with parabaloid collector 10 m in diameter is being build in Yerevan. The thermal power of this furnace will be 50 kW. It is projected to use this unit to study the aging of materials exposed to concentrated rays.

Several high-temperature solar furnaces with mirror diameters from 1 to 3 m are operating in the Institute of Electronics of the Uzbek SSR Academy of Sciences. Here experiments in the fusion of high-alloy steel, heat-resistant titanium, tungsten, and molybdenum alloys are underway. Solar power engineers of another Tashkent institute -- the Physico-Technical Institute -- are designing a solar furnace whose power will be more than 100 kW. It is projected to collect the radiant energy for this facility with a 15 m diameter reflector. The efficiency of this giant collector has been tested by Tashkent solar power engineers with models in which the diameter of the mirror bowl is 5 m.

It should be noted that with the increase in the collector dimensions, on the power of the solar furnace grows. But the temperature in it depends not on the diameter of the mirror surface, but on the accuracy of concentration of the rays, on the quality of the mirrors of which the reflector bowl is assembled. What then is the maximum temperature that can be achieved in solar furnaces? The temperature of the surface of the Sun is the theoretical limit, about 6000° Celsius. But in practice owing to energy losses as the rays travel through the atmosphere and due to their scattering by mirrors, the solar furnace temperature usually does not exceed 4000°. However, this is already quite enough for the Sun to cope with metallurgical problems.

It also turns out that the Sun is an excellent welder. Where metal of extra-high purity must be fastened it is quite indispensable. Evidently work has been found for the solar welding unit also where it is difficult to bring heavy electrical power generator, for example, in the desert, on mountain peaks, in outer space ...

Solar Energy /50

The globe is encircled by a yellow strip of desert. In order to take in this zone at a glance, one doesn't have to be a cosmonaut. All one needs to do is to spin a miniature model of our planet around with his hand -- a classroom globe. The belt of desert along the equator has stirred the imagination not only of schoolchildren struck by the extravagence and "mismanagement" of nature already in their first geography lessions. This amazing belt has also riveted the attention of scientists.

How better to place at the service of man the arid and lifeless lands? This though has long made restless more than one generation of investigators of numerous specialties. Plans for the purposeful conquest of deserts have been proposed also by solar power engineers. According to one of them, it is projected to build a unified global network of helioelectric power stations girdling the globe and feeding energy all the way to the poles continuously throughout the day. Calculations and some justification of the possibility of building this world-wide network of helioelectric power stations have been carried out by Ashkhabad solar engineer N.V. Linitskiy. They were published in the All-Union journal Geliotekhnika, originating in Tashkent.

Deserts occupy about 20 million square kilometers of the globe. Half of all of this area, as the project's author calculates, can be occupied for the location of solar electric power stations. N.V. Linitskiy regards as the most realistic at the present time schemes based on different versions of plans of solar thermal stations developed in the USSR. Their operating principles is based on collecting solar rays reflected from large flat mirrors into a single focus at which a steam boiler has been placed. Next follows the traditional approach of converting thermal energy into electrical.

The calculations of the project's author showed that even at today's level of technology, over the territory of unused deserts an entire necklace of solar stations with a total mean power of about 130 million kW can be built! This sould prove enough to meet mankind's energy needs not only for today, but also into the /51
next century, given the growing demand level.

The global network of solar power stations is of course a highly alluring, although schematic plan. And before commencing to act on it, no small amount of research is required. In particular, it remains to be found what consequences for the climate of our planet will come from tapping this enormous fraction of solar radiation. One must also study the inverse influence of this factor on the operating conditions of the solar power station.

As part of the construction of the global belt of solar power stations, one more interesting problem crops up. The colossal "tapping" of solar energy possibly will even cause cooling of the atmosphere, since when solar energy is converted into electrical there will be much less of it scattered in the form of heat.

Scientists even rejoice in the possible cooling; in fact today the planet is threatened with more of a heat increase which according to already-known forecasts in the future will intensify much faster, especially owing to the building of powerful electric power stations based on thermonuclear energy. According to physicists' calculations, the limit to the growth of their capacities will in fact become the fairly high heating of the Earth's atmosphere. Therefore it can be assumed that a combination of solar and thermonuclear power stations will prove very advantageous for the power budget of the Earth in the next century.

There remain no small number of problems to be solved also in improving the design of the solar power station as such. The plan of a solar electric power station in the 1950's by co-workers at the Power Institute imeni G.M. Krzhizhanovskiy for the Ararat dam in Armenia received the greatest renown. Drawings of the general view of this station covered pages of the entire world's popular-scientific press. In place of the customary high smokestacks typical of industrial landscapes with thermoelectric power stations or dams of hydroelectric stations, here you see first of all a gigantic bowl glistening with 1293 mirrors. Each is placed on a special cart. Altogether they comprise 23 automatic trains traveling along concentric rail lines. The cars move /52 slowly -- at the speed of the visible azimuthal sweep of the Sun across the firmament -- and direct the rays of our star toward the center of a spherical surface where at the top of a 35 m tower stands a boiler. According to the intention of the project's authors, it is a chamber filled with black metal piping. Water circulating in them, on being heated, is converted to steam warmed to 400° Celsius. It drives a turbine that rotates an electric generator. The rating of this electric power station is 1200 kW; the annual output of electric power is 2.2 million kWh. Also, the steam produced is suggested to be used to drive an absorption type refrigerator capable of producing 20 tons of ice an hour.

The authors of the major solar electric power stations, R.R. Aparasi, V.A. Baum, B.A. Garf and D.M. Shchegolev, reported on it in May 1954 in Tashkent at the Fifth All-Union Conference on Solar Power Engineering held there. And one more paper drew specialists' attention. It was presented by one of the authors of this book, G.Ya.Umarov, advancing his version of the large solar power station. Conference participants were able to become acquainted also with an operating model of the station, which was demonstrated in Tashkent's Park imeni Tel'man.

In the Tashkent project it was suggested to avoid expensive operations in laying out concentric rail lines (they had to form circles ensuring an especially exact alignment of the entire optical system of the mirrors) and the construction of automatic trains with carts. The absence of the latter at once then cut back on the large outlays for driving the complicated, not very reliable mechanical system and also in overcoming the frictional forces. The mirrors according to the Tashkent plan had to be installed at fixed points and synchronously rotated like sunflowers, following the Sun moving across the firmament.

The solar power engineer already familiar to us, N.V. Linitskiy, as early as 1946 advanced the idea of using stationary mirrors orienting solar rays toward a single point. According to his scheme the reflected rays had to be focused at one solar /53 kettle mounted on a high tower. However, the use of stationary and fixed mirrors had a substantial drawback: owing to the motion of the Sun across the sky the use coefficient of the reflectors became relatively small, only of the order of 0.6-0.65.

For several reasons, a large solar power station designed by Moscow solar power engineers was also not built in their time. Theoretical and experimental work in its improvement is now continuing.

Abroad another direction another direction in heavy-use solar power engineering is growing. Foreign specialists calculate that solar facilities operating in outer space will have the most economically advantageous indicators. Their ray-receiving surfaces, as shown by foreign experts, can continuously or nearly continuously be irradiated by the Sun, while the transformation of light energy into electrical by means of semiconductor batteries can be carried out there at a maximum efficiency.

The proposed project which was discussed in detail in the Tashkent journal Geliotekhnika provides for installing solar power stations on artificial Earth satellites whose orbit will lie in the equatorial plane. These satellite-stations will travel at an altitude of 36,000 km; this will ensure their constant presence over a specific point of the Earth. The electric current generated on the satellites is proposed to be transformed into electromagnetic radiation with the 10 cm wavelength. With appropriate antennas it will be directed toward receivers on Earth, where it will be converted in special units into direct electric current. Selection of the wavelength of 10 cm was due to the fact that this wavelength is virtually unabsorbed by the Earth's atmosphere, therefore the energy transfer from the satellite to the planet's surface will be carried out with slight losses.

What then is the size and weight of these future electric power station-satellites? According to the calculations of the project's authors, a station with a capacity of 10 million kW and an efficiency of 10% will have a solar battery more than 5 km in diameter and weighing 150 tons. /54

Specialists working on plans for solar electric power station-satellites stress that building these stations will avoid the further contamination of air, water, and soil, will permit the use of the remaining reserves of fossil fuel exclusively for the needs of the chemical industry, and will avoid the necessity of building large nuclear power stations.

Under Solar Sail

"Jean and Phyllis enjoyed strolling into space far from all inhabited worlds... For their own pleasure, they furrowed the expanses of the universe beneath sails.

"Their space yacht was something like a sphere, whose outer shell -- an uncommonly thin and light sail -- ballooned out and traveled in space by trapping the pressure of light rays. Jean thought up a truly amazing method of locomotion in space. Numerous black little blinds were arranged on the spherical sail of this little ship; the blinds were rotating or reversed at the will of the helmsman; by this maneuver the reflectivity of certain sections of the sail was changed ..."

This excerpt is from the fantasy novel of the famed French novel Pierre Boule, Planet of the Apes. However, flights into outer space beneath solar sails today no longer are a monopoly of science fiction writers. Engineers and scientists inspired by the idea of voyaging from planet to planet without expending fuel have invaded the land of fantasy with their sober mathematical calculations. And here is one of their conclusions: "Comparison of solar sails with other propulsors of continuous action showed that in the light of the present state of the art the most serious attention must be given solar sails." This view was expressed by the American specialists J.H. Hawk, F. Macmillan, and A. Tangey, which we cited from the book Izpol'zovaniye solnechnoy energii /55 pri kosmicheskikh issledovaniyakh [Solar Energy in Space Research], published by the Moscow publishing house "Mir."

Plans of space sailing boats are based on using the pressure of light discovered by the remarkable Russian physicist, Pyotr Nikolayevich Lebedev. By means of extremely subtle experiments, in 1899 he was able to prove the existence of light pressure on bodies. Light pressure beyond the Earth's atmosphere is the second factor, after universal gravity, that acts on a vessel.

For solar light pressure to begin to drive a craft, first of all a light sail is needed. It must be a thin plastic film coated with a layer of reflecting material. Modern chemical science makes it possible to build a sufficiently thin and light film for space sailing ships. According to the plans of one American specialist, a square meter of this material would weight 0.976 g, while the entire sail would weigh only 30-50 kg. Scientists have calculated that at some point the velocity of such a space sailing ship injected into Earth orbit would enable it to go beyond the sphere of attraction of our planet and set out on a voyage to distant worlds with "passing light." The shape of the trajectory of this flight was also found: the ship would move away from the Sun along a logarithmic spiral.

Thus, mankind is awaiting the age of the sailing fleet in outer space! This is in the future. But today? Today, the Sun is also an indispensable helper of man in mastering outer space. It is the most important source of energy powering spacecraft and artificial satellites. Solar photoconvertors made up of silicon semiconductor plates have been installed on these craft to generate electrical power. This kind of device appeared for the first time on the third Soviet artificial Earth satellite. Today panels of solar batteries have become commonplace. We often see them on television screens during direct transmissions from outer space. And how can one forget that the Sun's energy powered the first extraterrestrial land vehicle -- Lunokhod-1. For the full 10 plus months, the world scientific community closely followed its journey over the surface of the Moon. Then Lunokhod-2 was set on /56 its way...

Returning to the above-cited book, one would wish to cite one more excerpt: "A solar generator will somewhat surpass the chemical battery in those cases when power must be used for a prolonged time..."

Numerous projects for using solar energy also for earthly purposes are linked to outer space. The Italian journal L'europo recounted one such project: "The dream of man to ameliorate the climate of the cold regions of the planet by prolonging the hours of sunlight, to bring abundant precipitation to deserts, and to heat water in chilly seas evidently is fated to be realized fairly soon: the necessary extra sunlight can be directed into the needy territory by giant mirror reflectors launched into Earth orbit.

"In the view of experts this quite feasible project was developed by professor Aurello Robotti, of the Turin Polytechnic Institute. Enormous reflectors -- their working surface must be in the hundreds of square meters -- have to be brought into the given orbit in dismantled form and assembled in place (one can say that Soviet and American cosmonauts working in outer space have already taken the first steps in this direction).

"On completion of the installation, special land control stations like those that today direct automatic space stations, can orient the mirrors of the reflectors in the necessary direction. Thus, depending on users, the amount of additional sunlight can be dispensed, the duration of the "session" can be regulated, and so on. For the reflector to be constantly over the same place on the globe, calculations show that it must be launched to an altitude of 36,000 km.

"One reflector with a working surface of 3 km^2, in this orbit, is capable of illuminating on Earth on area of 87,000 km^2 one hundred times more strongly than it is illuminated by the Sun. Extending the days of sunlight opens up inexhaustible opportuni- /57
ties for manking.

"Specialists estimate that carrying out Professor Robotti's project involves not so much technical as economic difficulties. But however great the outlays, if jointly several countries take on the undertaking, the costs will be met in something like 20 years."

Yes, actually, today building an enormous reflecting surface does not appear to be an insurmountable technical problem. As for the actual idea of building an "artificial Sun," it is not a new one. Proposals to deploy in Earth orbit a gigantic film reflector have been expressed by numerous scientists, and today it is by no means simple to establish priority in this direction and the contribution of each author in elaborating this interesting idea.

One also should note that no appreciable influence on the power engineering of the planet or any tangible influence on climate or weather should be expected from the realization of the project "artificial Sun." On the other hand, it is doubtless true that the space mirror will prove a useful source of illumination. With it the polar night can be illuminated, for example, Noril'sk or any other large subpolar city.

The illumination produced by the "artificial Sun" will be 100 times brighter than moonlight at full Moon. Therefore, space mirrors evidently can find use also in illuminating at night regions of the globe with specially dense population and exceptionally developed transportation -- automotive, air, and water.

The search for effective means of utilizing solar energy is continuing. The famed Soviet chemist and Nobel prize laureate Academician N.N. Semenov advanced the project of utilizing the Moon for the purposes of terrestrial power engineering. He calculates that if it would be possible to cover the entire surface of the Moon with semiconductor photocells with fairly high efficiency of converting radiant energy into electrical and to find a method of transmitting this energy (using, for example, directed radio beams) to Earth, the Moon could in the future become a tremendous power station for Earth.

Progress in space solar power engineering is capable of playing no small role and of indirectly affecting Earth affairs. Here is what was written in this respect in the book already mentioned: "The bold plans of exploiting solar space power systems and extended research aimed at improving the technology of solar power engineering can help improve the economic characteristics of the use of solar energy in Earth conditions and bring the day closer when solar ground power systems will become economically profitable." /58

Horizons of the Future

Solar energy will be widely utilized by man in the twenty-first century. Many leading scientists maintain this. But what then do they represent as happening tomorrow?

The outstanding French atomic scientist Frederic Joliot-Curie proposed following an approach urged by nature, which utilizes the Sun's energy in plants by means of the green grains of chlorophyll. Joliot-Curie put it this way: "Even though I believe in the future of atomic energy and am convinced of this importance of this invention, however I maintain that the true turning-point in power engineering will occur only when we are able to achieve the massive synthesis of molecules analogous to chlorophyll or even of higher quality."

The remarkable Soviet physicist, Academician A.F. Ioffe pinned great hopes on the direct transformation of solar energy into electrical by means of semiconductors. He calculated that only one-third of the territory of the Karakumy desert could yield electric power twenty times more than all modern power stations. Bearing in mind the prospects of the use of solar energy in the deserts, the scientist wrote: "The Sun during millenia having formerly the scourge of the deserts will become its blessing."

The following words come from another famous Soviet scientist, Academician B. Konstantinov: "I hope that mankind will solve in the not distant future the question of the broad transformation of /59
solar energy into electrical. One would think that together with this the problems of climate and weather control would be solved."

We have already written about projects to compel the Sun to work in space for the good of the people of the Earth. There is the idea of submitting the possibility of turning the Sun "from its cosmic sweep" also toward our planet. We have recounted plans on using the solar "energy of evaporation." Each year our daytime star consumes it in an amount estimated at 40 billion tons of standard fuel! Only a negligibly small fraction of this colossal energy is utilized by man by means of hydraulic stations. But alongside these enormous resources engineers cannot blithely pass by. Tremendous projects to master them have appeared. Thus, it is calculated that if the Straits of Gibraltar are covered with a dam, the level of water in the Mediterranean in 10 years would drop 11 m, which would make it possible to build at the overfall of the levels a hydroelectric power station with a capacity of several million kilowatts. Projects have also been proposed for building canals in the deep depressions not far from the seas and oceans. Powerful hyraulic turbines can also be installed in these canals, through which water would flow by gravity.

A report appeared in the press stating that American scientist William Asher is developing a technology of using solar energy in order to obtain in the future fuel for electric power stations and industrial enterprises.

The scientist proposes that with gigantic artificial island-modules 1 x 1 km in size floating in the equatorial regions of the ocean solar energy is to be collected and utilized for decomposing seawater into hydrogen and oxygen. Then the chemical elements would be cooled to superlow temperatures and in the liquefied state transported by special tankers to thermal power stations on land. At the stations, in the reaction of combining the gases would give off great amounts of heat that would be expended in producing electric power.

The only project of combustion in these reactions is ordinary water and, therefore, the new technology will do much to solve the problem also of controlling environmental pollution, although this /60 fuel will evidently be more expensive than the traditional petro-leum, coal, and natural gas.

According to Asher's report, most of the components necessary for generating energy under this scheme have already been verified in various experiments and have proven themselves quite feasible in practice.

Yes, the use of solar energy opens up the possibility of transforming enormous territories and promises to give man the keys to controlling weather and climate. Important consequences of introducing the achievements of solar power engineerings should also be expected in improving the technology of production in many industries. Specialists calculate that by the end of this century and in the twenty-first century solar metallurgy will reach major scales of production, capable of producing metals of extra-high purity. And in fact tomorrow these materials will be particularly needed by technology.

Electrification owes its grand sweep to the possibility of transmitting electric power over large distances. And perhaps solar energy can also be thus transmitted," scientists have pondered. The answer was found: a light cable made of extremely fine glass fibers can become "conductors" of radiant energy. The diameter of each of them covered with a mirror casing is several hundredths of a millimeter. A beam of light entering such a fiber will bounce between its walls and, undergoing billions of reflections, will exit from its other end. When wound together, the fiber-filaments form a thick, but elastic cord -- a light cable. It was even found possible to unite it in a splice! For already several years engineers are using the "light conductors" in transmitting images.

A little fantasy -- and now before us ... a giant parablic mirror bowl on the roof of a factory, a tracking device that is continually rotating the collector aimed at the Sun. From the focus of the reflector, from where the solar "light spot" dazzles by its brightness one takes the beginning of the light cable. Into its end, as into an open pipe, a stream of concentrated light is directed. Further, moving through the light cable within the factory building, it zooms along individual light conductors to the work stations. Just as current along branching electric /61
lines! The light guides arrive at equipment with which welding, melting, and soldering of metal is carried out. Solar melting or soldering is especially valuable for the radio electronics industry, requiring ideal purity. By directing the beams through the transparent wall of a vessel, one can solder or weld parts in a vacuum, for example, within a radio tube. Part of the "light conductors" ends up beneath the actual ceiling and by means of special reflectors the room is flooded with golden light.

In order to economically utilize the Sun's energy in our planet, no small amount of work has to be done by both biologists, plant breeders, and agronomists, and even by representatives of many other fields of agricultural science. Let us recall that plants utilize only about 1% of the light energy absorbed by the green leaf in photosynthesis. This is a very small amount. Nonetheless, through this process more than 100 billion tons of organic compounds are formed on the planet. From them only about 0.2-0.4% is used for human food. It would appear to be a trifle. But in this "trifle" plants have stored so much light energy that, to obtain an equivalent amount of produce through chemical synthesis, mankind would have to direct all the energy that they now expend in all fields of human activity.

That is why scientists of many countries are concentrating their efforts to delve into the secrets of photosynthesis. In this way they hope to increase the efficiency of solar rays in this natural process. Using advanced agrotechniques it is not difficult to raise it 2%. Theoretically, there is a possibility of using 20-25% of solar energy obtained by the green leaf. This is an enormous foodstuffs reserve for rapidly multiplying mankind.

And it is not accidental that at the frontier between biology and technology was born the idea of trapping solar energy with algae. The American Journal Mechanical Engineering wrote about this project. In one of its articles it was stated that at the present time some researchers regard the "capture" of solar energy /62 by fast-growing algae as one of the promising methods of solar energy utilization. Algae growing in a body of water are "mowed" and stored in an autoclave for fermentation. The methane formed in the autoclave is burned, and the heat released during combustion is utilized in the usual way to generate electrical current.

Scientists of Uzbekistan proposed building plants to grow algae, in particular, Chlorella. This microscopic plant has a high efficiency of radiant energy use and can become an important source for protein and other valuable nutrients. To boost the efficiency of photosynthesis, it is proposed to utilize at these plants irradiation of algae with pulsed concentrated sunlight. A prototype of this device -- a miniature plant -- has been proposed by Uzbek scientists.

We are accustomed to speak of the "age of metal," "age of plastics," "age of cybernetics,"... But has the solar age begun? If so, then when? This will depend on the uniting of efforts by scientists in numerous specialties. No less vital to progress in solar power engineering is the consolidation of cooperation between states, and the direction of common efforts to achieving major projects in mastering the energy of the Sun.

The solar age will soon begin for mankind! And our star that for billions of years has lavishly bestowed radiant energy on Earth will faithfully serve its peoples.

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